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Microfocus X-Ray and Image Enhancement of Ceramics

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Abstract
Microfocus X-ray and image enhancement techniques were applied to hot-pressed silicon nitride test specimens containing selected subsurface defects. These NDE techniques are being investigated to determine their defect characterization capabilities in various ceramic material systems. Illustrations are presented of defect detection limitations for microfocus X-ray which are primarily associated with low radiographic contrast between defect and parent material. Examples are also shown of defect detectability and geometric sharpness obtained.in ceramic test specimens containing inclusions of high and low density with respect to the parent material.

Keywords
Nondestructive Evaluation

Disciplines
Materials Science and Engineering

MICROFOCUS X-RAY AND IMAGE ENHANCEMENT OF CERAMICS

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ABSTRACT

Microfocus X-ray and image enhancement techniques were applied to hot-pressed silicon nitride test specimens containing selected subsurface defects. These NDE techniques are being investigated to determine their defect characterization capabilities in various ceramic material systems. Illustrations are presented of defect detection limitations for microfocus X-ray which are primarily associated with low radiographic contrast between defect and parent material. Examples are also shown of defect detectability and geometric sharpness obtained in ceramic test specimens containing inclusions of high and low density with respect to the parent material.

INTRODUCTION

Microfocus X-ray and image enhancement techniques have shown potential to reduce the subjective interpretation of defects detected in ceramic materials.(1) The purpose of this study is to obtain a quantitative measure of the capability of these techniques for defect characterization in ceramic materials in terms of size, type, and location.

DISCUSSION

Radiography is widely recognized as a means of evaluating materials for subsurface defects. The applications and advantages of this technique are listed in Fig. 1. As is the case for most, if not all NDE methods, limitations are also known relative to defect detection and interpretation of radiographic film obtained using penetrating radiation. These important considerations are shown in Fig. 2.

Further indication of the importance of radiographic contrast between the indication of interest and the parent material is illustrated in Fig. 3. The difficulty in detecting low or comparable density defects in a material system, using visual interpretation means, is a function of the absolute contrast obtained on the radiographic film. Inclusions of high relative density, such as tungsten carbide (WC), produce a significant contrast enabling visual detection of inclusions in the tens of microns size range.

(1) Schuldies, J. J. and W. H. Spaulding, "Radiography and Image Enhancement of Ceramics," Proceedings of the 1977 ARPA/NAVSEA Ceramic Gas Turbine Demonstration Engine Program Review, March 1978.

The use of microfocus radiography (Magnaflux Corporation), as compared to conventional radiography, is being evaluated to take advantage of the benefits derived from a smaller X-ray source. Control of the focal spot size, shape, and intensity distribution at the X-ray emitter (or target) suppresses radiation outside of the primary beam, which is essential in achieving a high resolution X-ray image. Other advantages, such as geometric enlargements, may be obtained while suppressing the effects of parallax obtained in the X-ray image. These advantages are listed in Fig. 4. A comparison of the theoretical focal spot shape and intensity distribution obtained on the X-ray target for conventional and microfocus X-ray systems is presented in Fig. 5. The variation in X-ray beam intensity is shown in Fig. 6, as indicated by the pattern and degree of film blackening (film density measured in H and D standard units) obtained using a 100-kV microfocus X-ray unit and GAF-100 film. As shown, an elliptical area having minor and major axis dimensions of approximately 1.25 and 2.5 inches should be used for evaluation when film density variations must be kept to a minimum.

Image enhancement through the computerization of X-ray film gray-scale data is also being evaluated to determine the degree of improvement obtained in defect characterization. The basic system components (Spatial Data Systems Model 820) are illustrated in Fig. 7.

Several radiographic and image enhancement examples are presented in Figs. 8 through 10 (photographically reduced approximately 18 percent). Two hot-pressed silicon-nitride specimens (NC-132), nominally 0.25 inches (6.4 mm) thick, and a hot-pressed silicon-nitride (NC-132) radiographic step-block standard are shown in the radiographs. The microfocus X-rays were obtained using specific exposure parameters. These parameters were varied about an optimum, which was determined by visually examining the radiographic film for geometric sharpness and contrast of the known defects. Enhanced outputs, using an algorithm that combines high-pass filtering and contrast expansion, are also shown in Figs. 8 through 10 for test specimen number 316. The arrows indicate both the WC inclusion placed in the specimen and a naturally occuring low-density defect. The arrows in the radiographs also indicate detection of a linear, low-density defect in specimen number 231 and a 0.020 inch (.500 microns) diameter hole 0.005 inch (125 microns) deep in the step-block standard.

An additional technique that employs thresholding or gray-scale level slicing is shown in Fig. 11. A selected gray-scale level divides the radiographic data into two colors, black or white, depending on the distribution of film density data. The enhancement photo reveals three WC particles in test specimen number 325 instead of a single 100 micron WC inclusion. The size of the large particle, measured on this output, is in good agreement with this size objective. A color coded output of this inclusion at greater magnification is shown in Fig. 12. While only two color levels are used, the system is capable of electronically classifying gray-scale data into thirty color levels. Figs. 11 and 12 were photographically reduced approximately 18 percent.

The color coded output, in Fig. 12, also shows an electronic scan line that runs through the largest of the three inclusions in specimen number 325. The degree of film contrast or density variance associated with the scan line is electronically displayed below the inclusions. As shown, this trace deviates in the region associated with the inclusion indicating a significant change in film density.

CONCLUSIONS

The detection of a single high density defect (i.e., 50 micron WC) has been demonstrated using microfocus X-ray. The use of image enhancement was also shown to improve the visualization of details associated with fabrication type low-density flaws. Image enhancement outputs indicated the importance of establishing exact radiographic procedures to obtain constant film densities prior to further reconstruction using computer algorithms. Although the efforts conducted to date indicate the utility of radiography to detect high-density inclusions, further advances in technology are required to detect low-density defects of comparable size.

ACKNOWLEDGEMENTS

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- WIDE VARIETY OF MATERIALS
- INCLUSION DETECTION
- LINEAR DEFECT DETECTION
- COMPLEX GEOMETRIES
- EQUIPMENT AVAILABILITY

Fig. 1. Radiographic applications

IMAGE CONTRAST

PARALLAX DISTORTION

DEFECT TYPE - PARENT MATERIAL RELATIONSHIP

DEFECT ORIENTATION AND EXACT LOCATION

RESOLUTION AND SENSITIVITY

SUBJECTIVE INTERPRETATION

Fig. 2. Typical radiographic limitations for defect detection

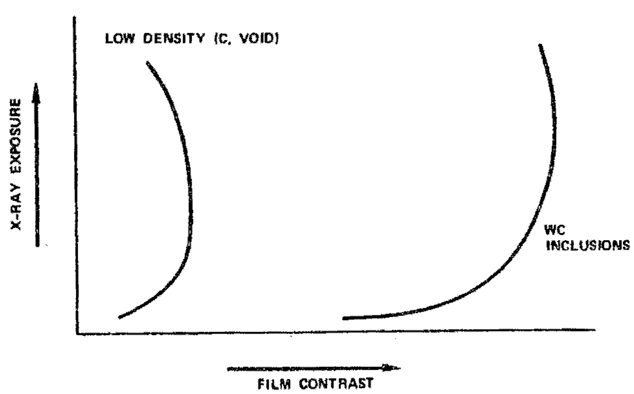


Fig. 3. Inclusion/parent material contrast relationship

CONTROL OF FOCAL SPOT SIZE, SHAPE, AND INTENSITY DISTRIBUTION

- REDUCED OFF-FOCUS (SECONDARY) RADIATION
- REDUCED PARALLAX EFFECTS
- IMPROVED EDGE RETENTION
- RADIOGRAPHIC ENLARGEMENTS

Fig. 4. Microfocus radiography advantages

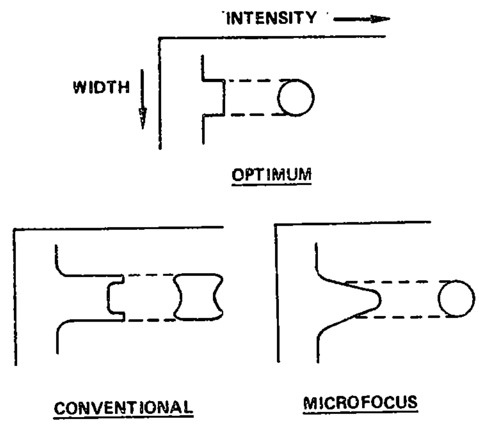


Fig. 5. Radiographic focal spot intensity distribution

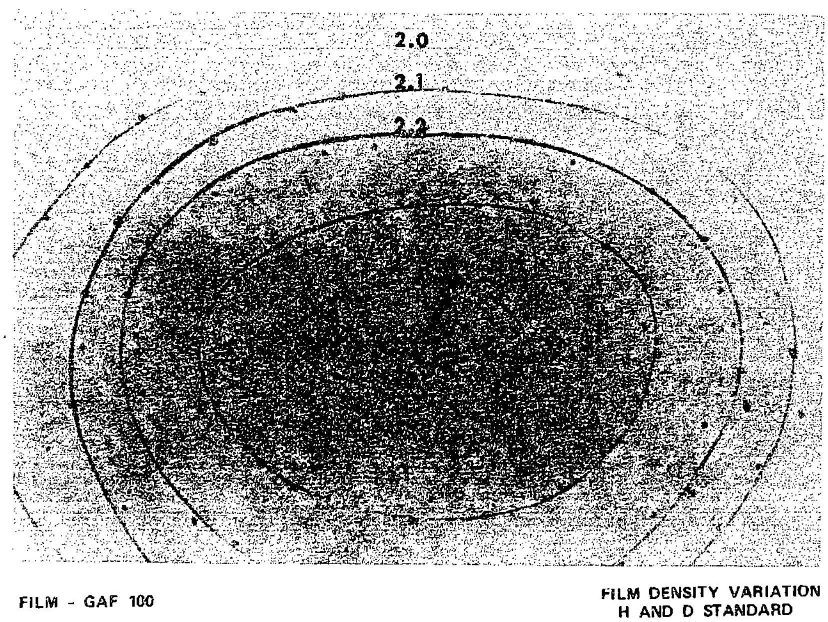


Fig. 6. Microfocus x-ray beam profile

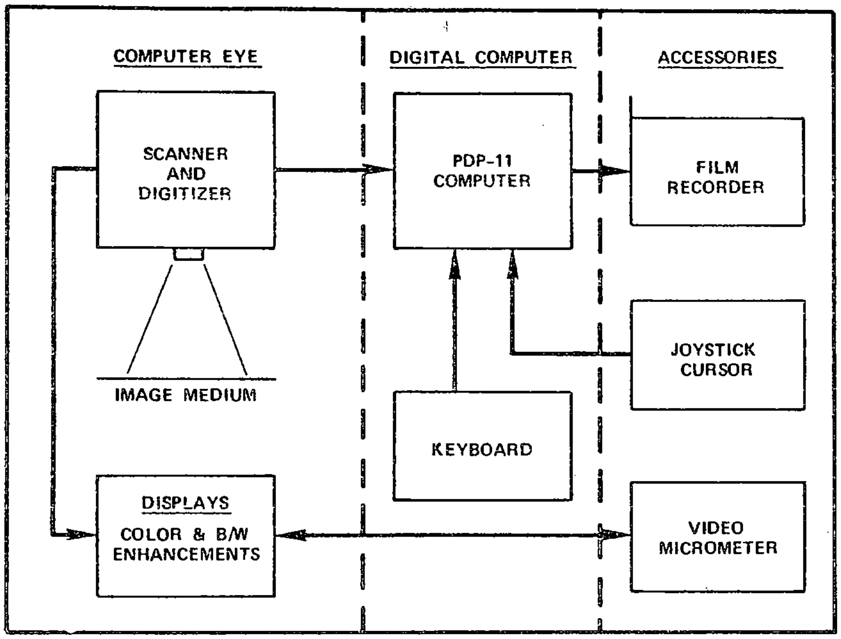
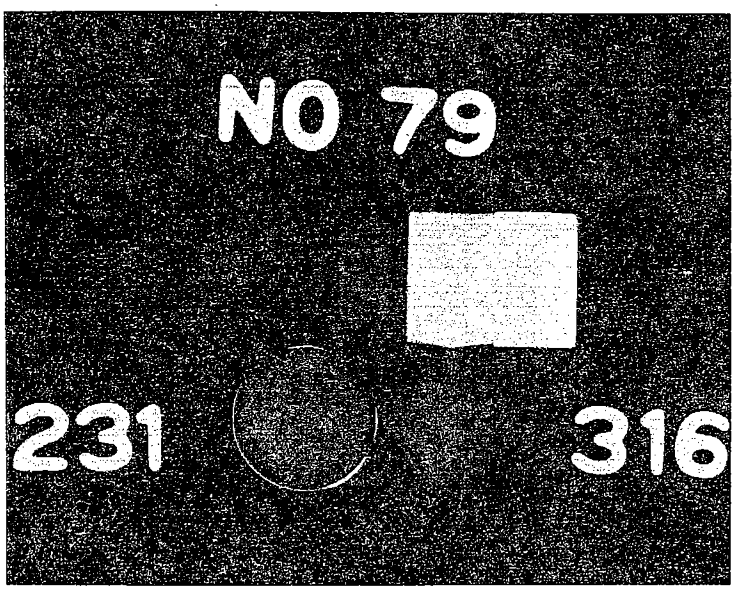


Fig. 7. Block diagram of computerized image enhancement system



MICROFOCUS X-RAY

HOT-PRESSED SILICON NITRIDE
NO. 231 - 200 MICRON SiC
NO. 316 - 50 MICRON WC

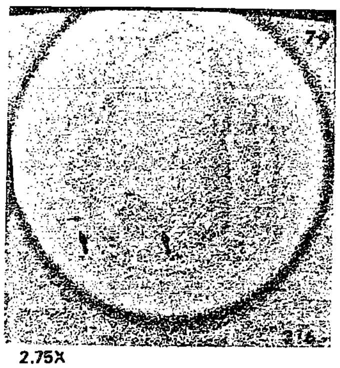
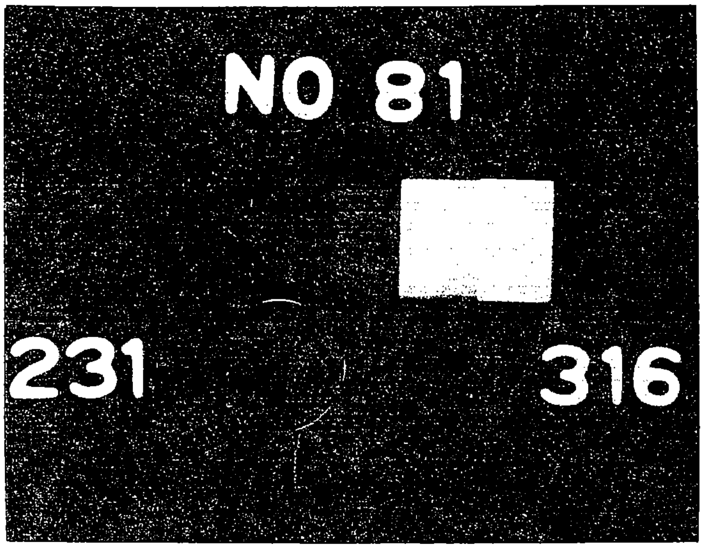
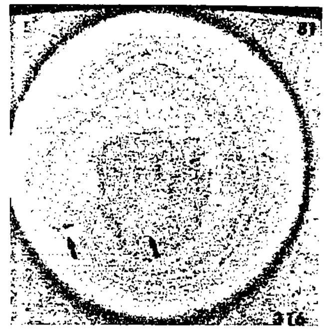


IMAGE ENHANCEMENT

FILTER/CONTRAST
EXPANSION ALGORITHM

Fig. 8. Radiographic and image enhancement - Examples





2.75X

IMAGE ENHANCEMENT

FILTER/CONTRAST
EXPANSION ALGORITHM

MICROFOCUS X-RAY

HOT-PRESSED SILICON NITRIDE
NO. 231 - 200 MICRON SiC
NO. 316 - 50 MICRON WC

Fig. 9. Radiographic and image enhancement - examples

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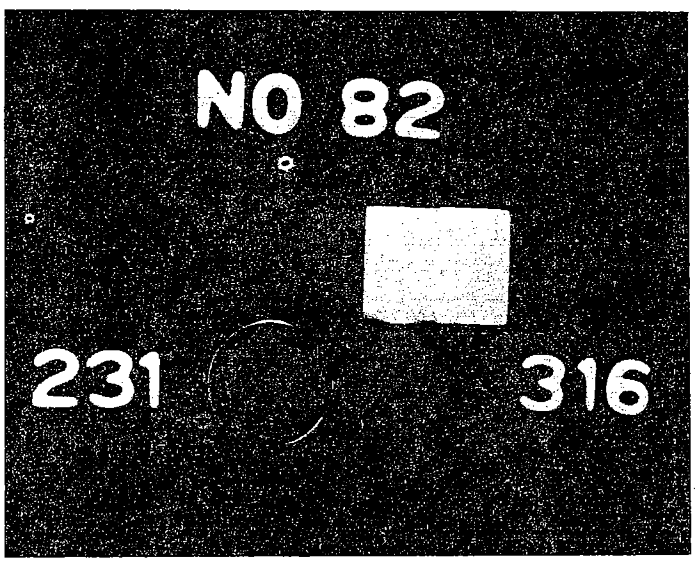
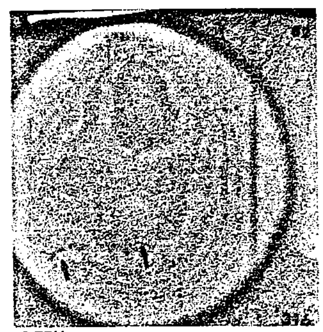




2.75X

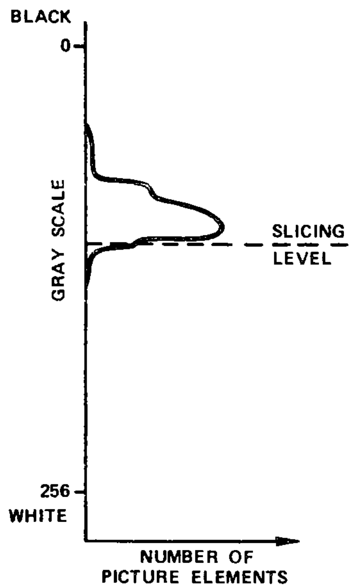
IMAGE ENHANCEMENT

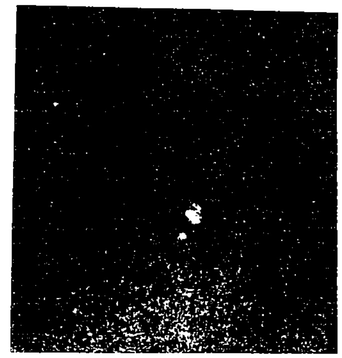
FILTER/CONTRAST
EXPANSION ALGORITHM

MICROFOCUS X-RAY

HOT-PRESSED SILICON NITRIDE
NO. 231 - 200 MICRON SiC
NO. 316 - 50 MICRON WC

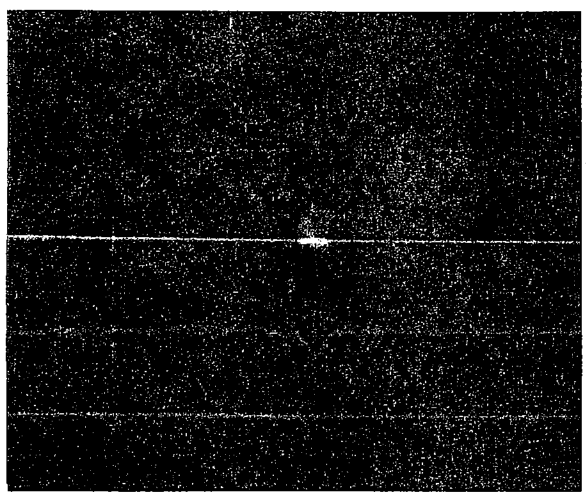
Fig. 10. Radiographic and image enhancement - examples





HOT-PRESSED SILICON NITRIDE
SPEC NO. 325
100 MICRON - WC
32X

Fig. 11. Image enhancement - thresholding



HOT-PRESSED SILICON NITRIDE - SPEC. NO. 325
100 MICRON - WC (≈70X)

Fig. 12. Color coding of radiographic data